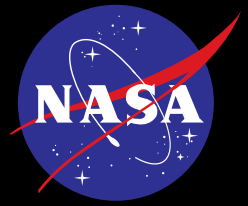


National Aeronautics and Space Administration



GSFC NEWS

tech transfer

Advanced Electronics

VOLUME 13, NUMBER 1 | WINTER 2015

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Nona
Cheeks



[FROM THE *Chief*

From the Chief

It is amazing how pervasive electronics have become in our post-modern world. When I gave the keynote address at the International Toy & Game Innovation Conference in Chicago last Fall, I saw electronics in practically every game I looked at!

Here at Goddard, electronics play a role in every mission: Sensors collect data electronically for processing and electronic transmission to ground stations, where electronic digital computers analyze and store the results. This quarter we highlight two missions: Soil Moisture Active and Passive (SMAP) and the Deep Space Climate Observatory (DSCOVR) each illustrating how electronics pervade Goddard's work. SMAP depends on taking ultra-sensitive microwave measurements, which are subject to Radio Frequency Interference (RFI). To get around that, a team of Goddard innovators developed unique RFI-mitigation strategies that may have applications in ground (as well as space) communications and radar.

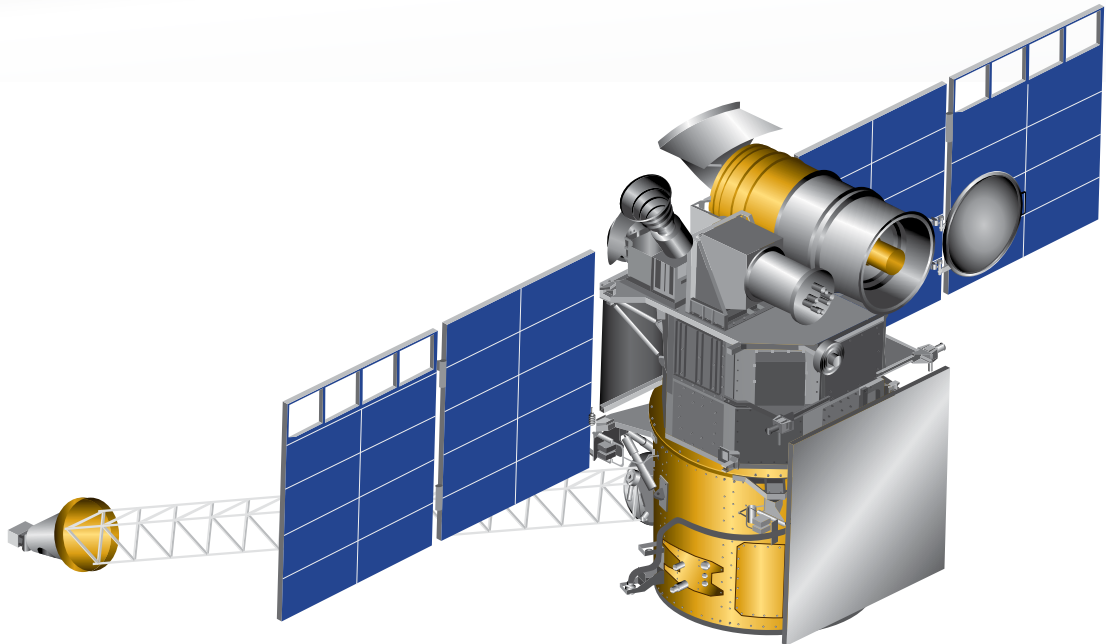
DSCOVR illustrates issues in aging electronics and space radiation – the mission uses a repurposed spacecraft that sat in a warehouse for more than ten years. A Goddard team tested the spacecraft and replaced suspect components before launch to an orbit at the first Lagrange point (L1), one million miles closer to the Sun than the Earth. From there, it will provide early warning of solar storms – and also collect information on how electronics are affected by radiation in deep space. Commercial applications for the resulting “space weather” reports range from the airlines to power grid operators.

I am also pleased to report that a Goddard team recently won an award for the design of SpaceCube, an electronic computer processing module designed for use in small spacecraft and sounding rockets. As usual we report highlights of some of the Small Business Innovation Research (SBIR) awards supervised by my office – including an advanced lidar that's being used aboard the International Space Station to detect atmospheric pollutants, computer-aided design tools to develop electronics for use in harsh environments that's now being supported by the U.S. Army, and silicon carbide-based ultraviolet detectors that may be used in consumer applications.

Finally this quarter we have no less than 27 technology disclosures, one patent application filing, 3 licenses and four patents to report – a great start to the new year!

Nona Cheeks

Chief, Innovative Technology Partnerships Office (Code 504)
NASA Goddard



► Artist rendition of NOAA's DSCOVR: Deep Space Climate Observatory
—IMAGE NOAA/NASA

Electronics are ubiquitous in our 21st century world, ranging from cell phones and tablet PCs to digital cameras and GPS navigation systems. Similarly, electronics are found in all spacecraft. They are essential for communications, guidance and control systems as well as providing the essential data collection and processing functions in scientific instruments.

Indeed, to a surprisingly large extent, aerospace development was responsible for the explosion of electronic technologies in the 20th century. The need to shrink the heavy, power-hungry, vacuum-tube based electronics of the 1940s and 1950s to fit the very limited space, power and weight budgets available in early satellites and missiles was a tremendous challenge, and led directly to the development of transistor-based miniature electronic systems and integrated circuits. Among the leading groups

doing such work was the atmosphere and astrophysics division of the Naval Research Lab, which built the instrumentation for the U.S. Vanguard satellites. Many engineers and scientists from that division later moved to NASA, forming the original core team at what is now the Goddard Space Flight Center. Today, Goddard engineers are at the forefront of advanced electronics development, continuing to push the state of the art forward as they strive to get the most scientific results possible within the still limited space, weight and power available in today's spacecraft. In this issue, we focus on two spacecraft: the Soil Moisture Active and Passive (SMAP) mission and the joint NASA-NOAA Deep Space Climate Observatory (DISCOVR) mission. We will also look at Goddard's electrical engineering division, known as Code 560, where much of the development work to support those missions was accomplished.

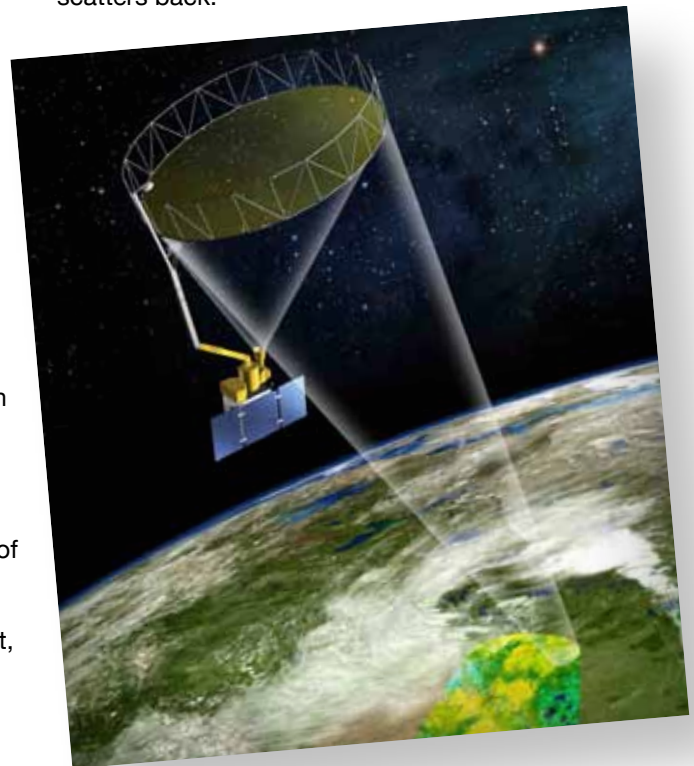
Applications

On January 31st, Soil Moisture Active and Passive (SMAP) reached orbit and began its three year mission to create high resolution maps of moisture in the top five centimeters of soil, world-wide. This will fill a significant gap in knowledge of how water is distributed, with a wide range of applications in agriculture, meteorology, climate science and hydrology. The spacecraft and its instruments will update these maps every two to three days throughout the mission, providing unprecedented data on seasonal and year-to-year changes in soil moisture and mapping how the moisture freezes and thaws. This is expected to allow prediction of significant events including floods and droughts, and improve climate change models.

The mission is crucial because understanding the moisture content in soil is crucial to developing reliable climate models. As the Jet Propulsion Laboratory (JPL) SMAP mission handbook notes: "Soil moisture controls the evaporation and transfer of water and heat from Earth's land surface and plants to the atmosphere. Just as perspiration helps maintain our body temperature, soil moisture and its evaporation help regulate Earth's surface temperature. Climate change may also have profound impacts on Earth's freshwater resources in the future. Understanding how climate change may affect water supplies and food production is crucial for policymakers. Current climate models produce widely differing estimates of how much water will be available regionally in the future. The SMAP mission will help bring these estimates into closer agreement, increasing our confidence in projections of regional future water availability."

To generate the maps, SMAP is equipped with two instruments – an active synthetic aperture radar and a passive radiometer – which both measure water content in the top five centimeters of soil. They do this using

a mechanism familiar to anyone who uses a microwave oven – water molecules respond to microwave energy by vibrating, thus heating up. The reverse of that process also occurs: water molecules, including those in soil, emit small amounts of microwave energy, thus cooling down. How much energy is emitted depends on the water's temperature. The emissions are terribly weak, so an extremely sensitive instrument (in SMAP's case, an L-band radiometer (GSC-16976-1) developed at Goddard) must be used to detect them. The radiometer is a passive instrument, measuring the natural emission from planetary water. It works in parallel with the JPL-developed active radar, which sends pulses of microwave energy and measures how much of that energy scatters back.



► Artist concept of NASA's Soil Moisture Active Passive mission.

—IMAGE BY NASA/JPL

The two instruments complement each other. According to the mission handbook, the radar has a relatively high 3 kilometer spatial resolution but lower absolute accuracy than the radiometer; which in turn has a much lower spatial resolution of 40 kilometers. Science processing software, (case number GSC-16744-1) developed at Goddard, combines data from both instruments to give results with better resolution and accuracy than either instrument could generate alone.

In addition to developing the L-band radiometer and science processing software for the mission, Goddard provided the deputy project scientist, Peggy O'Neill, for the mission, which is managed by the Jet Propulsion Lab.

Goddard Innovations

There are many challenges in developing new space-based instruments. For SMAP, one challenge stands out: protecting the sensitive radiometer and radar receiver from radio frequency interference (RFI). RFI is familiar to anyone who listens to AM or FM radio – one station interferes with another that's RFI; and it's becoming more and more of a problem for space-based instruments as more people use wireless devices, which emit radio frequency signals.

Goddard's SMAP radiometer operates in a 1400-1427 MHz band which is reserved for scientific use by U.S. and international law. Unfortunately, as noted by the team which developed SMAP's RFI mitigation strategy: "Although transmissions are forbidden at these frequencies by international regulations, ground-based, airborne, and spaceborne radiometric observations show substantial evidence of out-of-band emissions from neighboring transmitters and possibly illegally operating emitters. The spectral environment that SMAP faces includes not only occasional large levels of RFI, but also significant amounts of low-level RFI equivalent to 0.1 K to 10 K of brightness temperature at the radiometer output. Such low-level interference would be enough to jeopardize mission success without an aggressive mitigation solution including special flight hardware and ground software capabilities of RFI detection and removal."

To deal with the problem, an engineering team led by Goddard's Dr. Damon Bradley developed "a multi-domain approach to RFI mitigation (case number GSC-17030-1)." Their approach involves digital signal processing both on the spacecraft and on the ground. The on-board system uses "an innovative on-board digital detector backend with digital signal processing algorithms to characterize time, frequency, polarization, and statistical properties of received signals. Almost

1000 times more measurements than conventionally necessary are collected to enable the ground processing algorithm to detect and remove harmful interference." In addition, "Multiple RFI detectors are run on the ground and their outputs combined for maximum likelihood of detection to remove RFI within a footprint. The capabilities of the hardware and software system are successfully demonstrated using test data collected with the SMAP radiometer engineering test unit."

According to Dr. Bradley, there should be many other applications for the RFI mitigation techniques developed by his team: "Anybody in the communications and signal processing arena can benefit from this technology. It's complementary to us because to radiometers, communications are interference. But there are certainly applications in signals intelligence, detecting buried signals in noise. It might be usable in cell phones and other low-power radios. The communications and radar communities will see major benefit from this work."

The high resolution moisture maps delivered by SMAP also have a broad range of applications. According to the mission handbook, literally hundreds of end-users have already attended workshops to prepare for the mission. Areas expected to benefit from SMAP data include weather and climate forecasting, prediction of droughts and wildfires, early warning of floods and landslides, agriculture, human health and even national security: "The integration of soil moisture has been determined to be the single most critical parameter in state-of-the-ground models. Soil moisture and freeze/thaw data are also key to a broad array of military and civil works capabilities including road and bridge building, dam and levee assessment/construction, and tactical decision aid design and development."



► Map showing the impact of drought on California's farms, forests, and wild lands.

—PHOTO BY NASA

[APPLICATIONS *Repurposing a Spacecraft - Triana becomes DSCOVR*

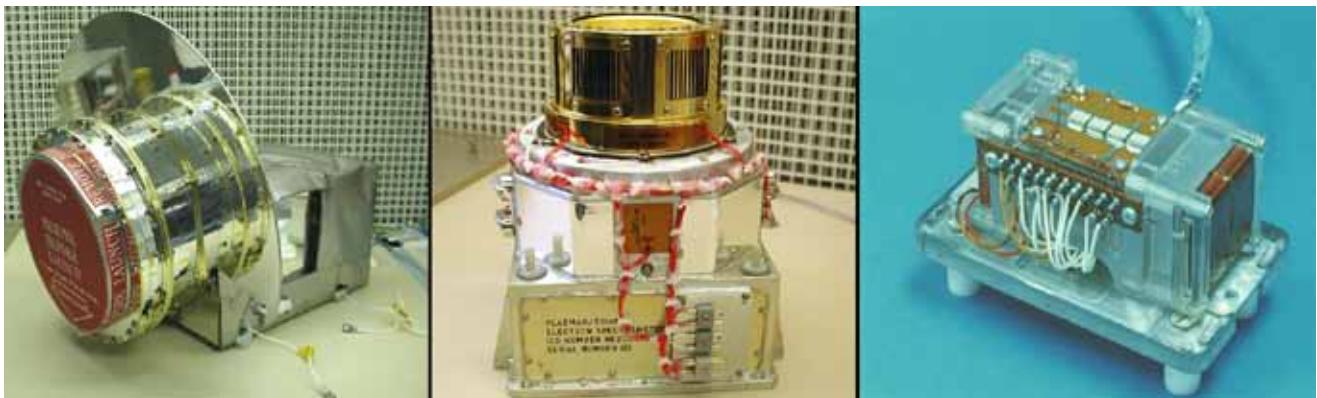
Applications

On February 11, 2015 a Space-X Falcon 9 rocket lifted off from Cape Canaveral Air Force Station, beginning a long-delayed mission to park a spacecraft at the 1st Lagrange point (L1), in a solar orbit one million miles closer to the Sun than the Earth. From that location, it will provide early warning of solar storms which can have significant effects on spacecraft and ground based electronic systems. It will also carry out a series of earth-and space-science observations that were planned almost two decades ago.

The spacecraft was built for NASA Goddard under an earlier program called Triana, which would have focused on Earth observation. Triana's primary instrument was a high-definition camera capable of sending continuously updated color imagery of the Earth as suggested by then U.S. Vice President Albert Gore, Jr. Triana would have been a NASA Earth-science mission with solar wind (and other space radiation) measurements as a secondary goal. However, while the spacecraft was built, changing priorities meant that it was never launched – instead being stored in a clean room for more than ten years.

Meanwhile, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Air Force found themselves in need of a new platform for “space weather” observations, particularly solar wind measurement to provide early warning of Coronal Mass Ejection (CME) and other events that can interfere with satellite operations. Since 1997, those observations have been provided by NASA's Advanced Composition Explorer (ACE) satellite, which has been monitoring the Sun from L1 and has exceeded its design lifetime. In 2008, NOAA and the Air Force paid to have Triana (renamed DSCOVR) removed from storage for testing. NOAA then decided to upgrade Triana – among other things, relocating two instruments. The spacecraft would now have a primary NOAA mission of space weather observation and solar storm warning, with secondary NASA missions of earth and space science measurement.

DSCOVR's instruments include a Solar Wind Plasma Sensor and Magnetometer (PlasMag) and associated Faraday Cup, which NOAA will use to measure solar wind velocity distribution and the magnitude and direction of the solar wind magnetic



► Three instruments will help measure the solar wind on the DSCOVR mission: (shown from left to right), the Faraday cup to monitor the speed and direction of positively-charged solar wind particles, the electron spectrometer to monitor electrons, and a magnetometer to measure magnetic fields. —PHOTO BY NASA

field. These are the primary instruments which will be used to predict solar storms. NASA's instruments on DSCOVR include the National Institute of Standards and Technology Advanced Radiometer (NISTAR), which will measure whole absolute irradiance integrated over the sunlit face of the Earth – a vital measurement for climate science applications, a Earth Polychromatic Imaging Camera (EPIC) that will image the sunlit side of the Earth for science applications such as measuring ozone, aerosols and clouds, an Electron Spectrometer (ES) that will generate high temporal resolution (<1 sec) solar wind observations, and a Pulse Height Analyzer (PHA) to provide real-time measurements of particle events that may impact DSCOVR's electronics.¹

While testing in 2008 showed that the spacecraft was in generally good shape – only the batteries needed replacement – concerns remained about some spacecraft components through the Government-Industry Data Exchange Program (GIDEP). According to Goddard's Robert C. Smith: "When we pulled the spacecraft from storage in 2012 for refurbishment, we evaluated shelf life on components and also checked the GIDEP database. DSCOVR had alerts on power converters in a number of electronic boxes. We tested all the suspect power converters and needed to replace some in the NISTAR instrument. We also moved the magnetometer to the end of a boom, further away from the spacecraft as it's now a primary instrument for solar observations. And we relocated the electron spectrometer from the end of the boom to the propulsion module."

One major change from the original mission is orbital insertion to the L1 point. Triana was originally planned for launch on Space Shuttle mission STS-107, and would have used a Goddard-developed Gyroscopic Upper Stage for transfer to a Lissajous orbit about the L1 point.² DSCOVR, on the other hand, was launched on a Falcon 9 booster from Cape Canaveral, and is using a faster transfer orbit, according to Smith: "We found a quicker route to L1." According to NOAA, DSCOVR is expected to reach the L1 point 112 days after launch.

Commercial and academic partners involved with Goddard in the DSCOVR project include Boston University, the University of Maryland,

Massachusetts Institute of Technology, Smithsonian Astrophysical Observatory, Universities Space Research Association, and SciGlobe Instruments & Services, LLC. NOAA will distribute solar storm warnings and observations through the Space Weather Prediction Center (SWPC) in Boulder, Colorado. Users are expected to include "power grid operators, airlines, and satellite navigation customers who will be impacted by the geomagnetic storms".³ NASA will be responsible for Earth and Space Science instrument data, which will be processed at Goddard and made available to the public through the Atmospheric Science Data Center at NASA's Langley Research Center.⁴



► NASA Goddard engineers ready the Deep Space Climate Observatory (DSCOVR) spacecraft for shipment to Cape Canaveral. —PHOTO BY NASA

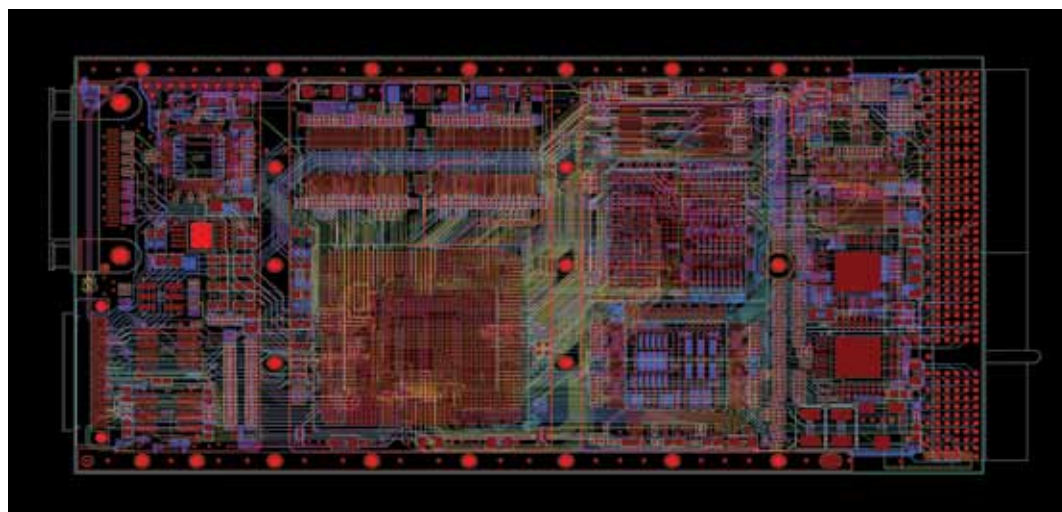
¹NOAA Satellite and Information Service Deep Space Climate Observatory (DSCOVR), NOAA web site, <http://www.nesdis.noaa.gov/DSCOVR/pdf/DSCOVR%20-%20Program%20Overview%20Info%20Sheet.pdf>, accessed February 23, 2015. ²Martin B. Houghton, "Getting to L1 the Hard Way: Triana's Launch Options," Presented at Libration Point Orbits and Applications, June 10-14, 2002, Girona Spain, NASA NTRS web site, <http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020081116.pdf>, (accessed February 26, 2015). ³Mission Information – DSCOVR: Deep Space Climate Observatory, NOAA web site, <http://www.nesdis.noaa.gov/DSCOVR/mission.html> (accessed February 26, 2015). ⁴DSCOVR: Deep Space Climate Observatory, NOAA web site, <http://www.nesdis.noaa.gov/DSCOVR/pdf/DSCOVR-facts-Jan15.pdf>, (accessed February 26, 2015).

Goddard's SpaceCube Team wins Global-Wide Military/Aerospace Award

Tom Flatley, head of Goddard's Science Data Processing Branch (Code 587) was pleased to announce that the SpaceCube v2.0 Processor Card (GSC-16700-1) has been selected as a 2014 Mentor Graphics Technology Leadership Award winner. The SpaceCube Processor Card design team consists of Dave Petrick/587, Dennis Albaijes/561, and Banks Walker/ASRC. Teams from sixteen countries competed for awards in six categories, and the SpaceCube won over a BAE Systems team's binocular helmet mounted display in the Military/Aerospace category. The Mentor Graphics Technology Leadership Awards honor engineers who use innovative methods and design tools to address today's complex Printed Circuit Board (PCB) systems design challenges and produce industry-leading products. Judges selected SpaceCube based on the following criteria: 1. Complexity of achieving a reliable PCB with back-to-back Field Programmable Gate Arrays (FPGA), 2. An innovative Power Distribution Network (PDN), 3. The amount of quality

analysis and tradeoffs steering the end product optimization, 4. The highest leads per device in the Military/Aerospace category compacting over 450 pins per square inch, and 5. For supporting data rates at some three gigabits per second. The innovations for the SpaceCube v2.0 Processor Card are patent-pending.

The SpaceCube v2.0 flight design builds on nine years of experience with past SpaceCube processors, which have been flight proven in 5 applications including on-board image processing during Hubble Space Telescope Servicing Mission 4, software mitigation of radiation induced electronic upsets aboard the International Space Station (ISS), a multi-function avionics package aboard the joint NASA-DoD Small Rocket/Spacecraft Technologies (SMART) sounding rocket, central avionics for the Space Test Program (STP) on ISS, and a SpaceCube v2.0 Engineering Model on ISS advancing prior technology demonstrations. The SpaceCube program is in the process of delivering three additional units for a follow-on STP ISS payload and one unit for a GPS sounding rocket demonstration.



► Rendering of the SpaceCube v2.0 Data Processor Card. —PHOTO BY NASA

Q. *Tell me about the Electrical Engineering Division*

Wes Powell: Code 560 consists of 9 branches ranging from flight command and data handing to instrument electronics and a branch at Wallops that works on suborbital systems. We have a huge range of technology under development. My job is coordinating technical activities in the division. The biggest part of my job is to align the ideas and energy of our innovators to address the strategic needs and opportunities of Goddard.

Q. *How did you personally get involved with Goddard?*

Wes Powell: A bit of a family connection – my Dad was a contractor here so I was familiar with the work. It's a place with a huge variety of things to work on, and that hasn't changed. Few places offer as many challenging things to work on.

Q. *Any trends you've noticed over your career?*

Wes Powell: Any organization evolves over time. Currently there's a lot of interest in smaller spacecraft and instruments – CubeSats and SmallSats. That's not to say that large spacecraft are not in our future. In engineering we're driven by the needs and interests of scientists at GSFC. They're our customers.

Q. *What's it like to work in engineering at Goddard?*

Wes Powell: Depending on where you are in a missions life-cycle, you are designing to different requirements. Some of us work collaboratively with scientists to explain



Wes Powell

ASSISTANT CHIEF
OF TECHNOLOGY,
ELECTRICAL
ENGINEERING
DIVISION

Code: 560

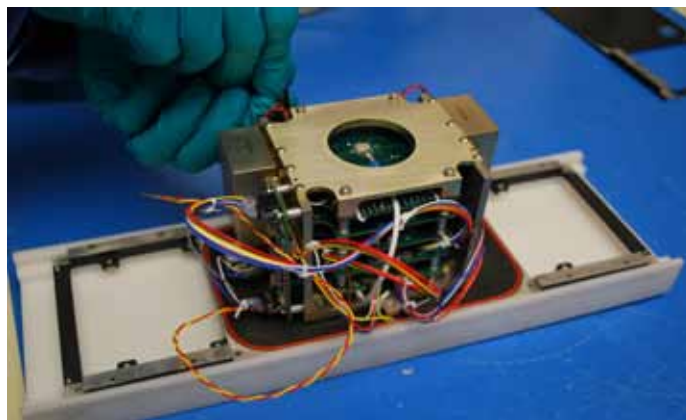
Years with NASA: 26

Education: MS in
both Electrical and System
Engineering.

what's achievable and to understand from them what they need to do. Early in programs it's very collaborative.

Q. *Has SBIR/STTR played a role in any of this work?*

Wes Powell: It has! When we recognize needs to support customers and do future missions, sometimes it's something we should do internally, and sometimes it makes sense for others to do.



► This close-up shows the ion/neutralized mass spectrometer that a Goddard team developed for two different CubeSat missions.

—PHOTO BY NASA

[INTERVIEW WITH *Damon Bradley*

Interview with Innovator

Q. *How did you get into engineering?*

Damon Bradley: I've had a life-long interest in tinkering and mathematics. I grew up in South Philly and I am the youngest of five. As a child, whenever my siblings brought home their old science textbooks, I used to copy experiments from them. Much later, one of my AP physics instructors taught me ham radio and Fourier Transforms in high school. From there I was introduced to digital signal processing (DSP) at Pennsylvania State University, and I've been working on it ever since.

Q. *How did you get into Goddard?*

Damon Bradley: Through my involvement in the National Society of Black Engineers at Penn State – I was chair of their telecom committee, responsible for the member email list and chapter website. A friend had been an intern here at Goddard and got a couple of Goddard representatives to give us a presentation on employment opportunities. I filled out an application, and later, on my way to an interview with Microsoft, I received an internship offer “that I could not refuse” from Dr. Dan Krieger for the summer of 2001.



Damon Bradley

LEAD COMPUTER
ENGINEER AND
DIGITAL SIGNAL
PROCESSING
TECHNOLOGY
GROUP LEADER

Code: 560

Years with NASA:
Started as an intern in 2001

Education: PhD,
Electrical Engineering.

I started at Goddard as a civil-servant Co-Op in the fall of 2001, working on various communications systems and channel coding projects. This work led to other projects in adaptive optics and radar signal processing. I started my own DSP technology group in 2008 within my branch to address the growing need for on-board science instrument signal processing, and the lack of personnel trained in the digital signal processing discipline. I started with five people – four of them more senior than me, and we've worked together ever since.



► SMAP's radiometer, prior to its installation aboard the spacecraft. —PHOTO BY NASA

Q - Tell me about your work on SMAP

Damon Bradley: I started working on SMAP, shortly after starting the DSP technology group, invited by Dr. Jeff Piepmeier, SMAP instrument scientist. He'd already worked on a project with the University of Michigan to develop RFI mitigation techniques and developed an approach using higher order statistics to detect RFI. There was a big debate early on whether to use those algorithms or not in the form of a digital back-end processor, known as the radiometer digital electronics (RDE) subsystem for the SMAP radiometer. I came up with an efficient way to implement those algorithms in hardware, and then became DSP lead on SMAP. Our success in the lab, developing an early low-cost prototype of the RDE led to journal and conference publications and five spin-off projects. I even applied for a patent. Another colleague received a patent on some related work. Research questions I had about the SMAP algorithms led to my PhD dissertation topic: New Algorithms for Detection of RFI, Based on Information Theory - the first time that's been done. SMAP was a gift that kept on giving! I took my family to the SMAP Launch at Vandenberg Air Force Base in California. SMAP launched successfully and is currently in orbit. I am eager to see the results when the SMAP radiometer will be switched on for the first time in the mission in the next few weeks.

Q - I understand you've also invented something called a Science-defined Signal Processing Module (GSC-16502-1)?

Damon Bradley: We're struggling with exactly what to call it... Think of a smart phone: On any smart phone, you have one standard computer that you can customize to your liking by downloading apps to it. Our innovation lets you do something similar, by implementing custom instrument signal processors. The idea of it is to have an electronics module consisting of one common digital electronics board, customizable daughter-cards that plug into it, and customizable "apps" called FPGA designs that have been organized into a NASA center-wide library that I developed in a prior research effort. I designed the module in a small form-factor which would fit a variety of spacecraft, and it's customizable for a wide variety of science instruments – portable radiometers, energetic particle detectors, planetary and earth altimeters, multi-spectral imagers, plasma wave spectrometers and electric and magnetic field monitoring instruments. In each case, the module can be configured to replace the custom electronics that would otherwise be designed for each instrument. We designed it in-house with a contractor involved for PC board layout. We've had a commercialization study done that suggested it might be useful in agricultural remote sensing applications.



► NASA's Soil Moisture Active Passive (SMAP) observatory, on a United Launch Alliance Delta II rocket, launches at 6:22 a.m. PST (9:22 a.m. EST) Saturday, January 31, 2015 from Space Launch Complex 2, Vandenberg Air Force Base, Calif. —PHOTO BY NASA

[INTERVIEW WITH *Bob Smith*

Interview with Innovator

Q How did you get involved with the space program in general and Goddard in particular?

Bob Smith: My Dad worked for Westinghouse Electrical Systems Group, and regularly brought home publications like Aviation Week. I spent my youth looking at pictures of airplane cockpits trying to figure out what every switch nob and dial did, and that drew me to aerospace. I wanted to be a pilot, when that didn't work out I stayed with the aerospace field, becoming an engineer. Bill Guitt at Ford Aerospace hired University of Maryland aerospace engineers for the Landsat IV and V control centers. I worked there from 1985-1988, then went to Lockheed for the Hubble deployment, and following that went to NASA on the Extreme



Bob Smith

DEPUTY PROJECT
MANAGER - DSCOVR

Code: 426

Years with NASA: 24

Education: MS, Space
Studies

UV explorer.



► The solar arrays on NOAA's Deep Space Climate Observatory spacecraft, or DSCOVR, are unfurled in the Building 1 high bay at the Astrotech payload processing facility in Titusville, Florida, near Kennedy Space Center. —PHOTO BY NASA

Q. *You were the Triana Instrument Systems Manager. Tell me about how the mission started out?*

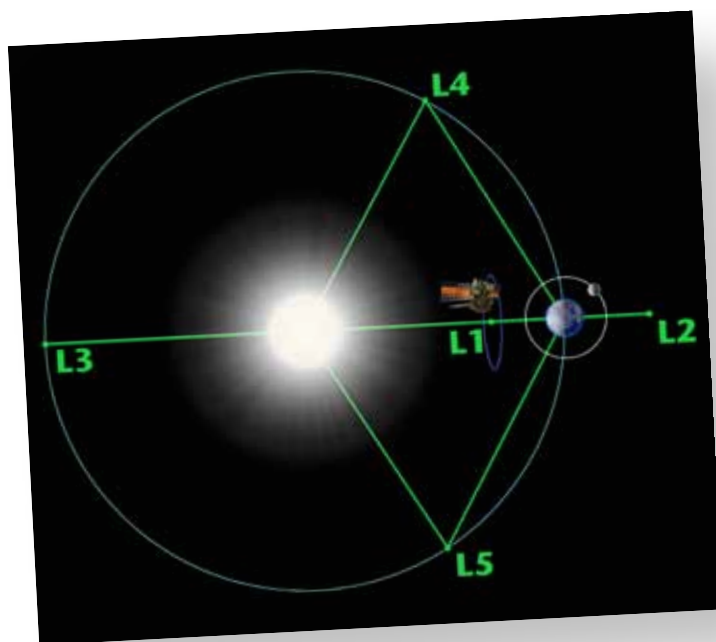
Bob Smith: I'd worked on four HST missions, and decided it was time for a change, so I talked to [Goddard Project Manager] Jim Watzin, and he brought me on as Instrument Systems Manager for Triana. Getting the news that we weren't going to launch was tough. We wound up having a pre-storage review instead of a pre-ship review. We were all ready to go but lost our spot on the space shuttle manifest.

Q. *Tell me about coming back to Triana - now called DSCOVR - after a ten year break?*

Bob Smith: There had been a couple of times when I got called to do studies – in 2007, Jim Watzin called and we put together a cost & schedule estimate, and in 2008 NOAA provided NASA with exploratory funds to bring the spacecraft out of storage for a checkout, and then put it back in storage. Afterwards, NASA directed us to remove the two earth science instruments for refurbishment and recalibration. I managed the effort to do that. In 2012, NOAA paid to have the spacecraft pulled out and refurbished for launch as DSCOVR.

Q. *How does DSCOVR differ from the original TRIANA concept?*

Bob Smith: For the most part the mission design remains the same. We found a quicker route to L1. Since the primary mission is now space weather, we took a more diligent look at spacecraft magnetic fields, and moved the magnetometer further away from the spacecraft as it's now a primary instrument. It took the place we intended for the electron spectrometer, so we found a new location for that near the spacecraft main body. Since it's now a NOAA mission we operate from their control center in Suitland, instead of Goddard. We had planned to have a data center at the Scripps Institute for Triana, instead NOAA will be using their data center in Boulder, CO.



► Diagram of the five Lagrange points associated with the sun-Earth system, showing DSCOVR orbiting the L-1 point. Image is not to scale. —IMAGE BY NASA

Q. *Can you tell me a little about the Pulse Height Analyzer (PHA)?*

Bob Smith: It's a very simple instrument, basically just a circuit card with memory chips that are constantly monitored to detect errors that result from space radiation.

Q. *What commercialization opportunities do you see for DSCOVR technology or data?*

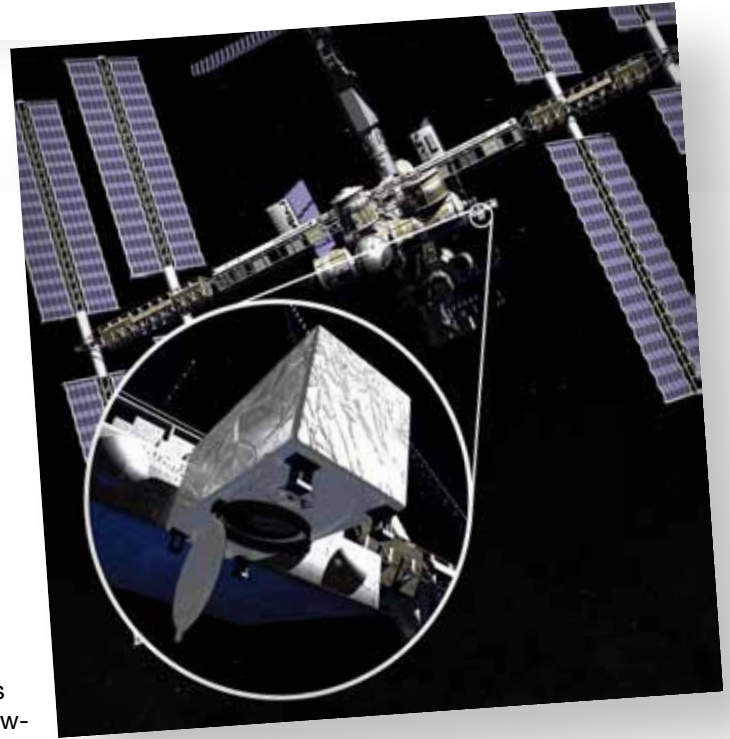
Bob Smith: The interagency agreement has NOAA responsible for commercialization – there are lots of applications for space weather data.

Advanced Lidar For Atmospheric Particle Sensing

NASA's Cloud-Aerosol Transport System (CATS) system arrived at the International Space Station (ISS) on January 12th. CATS is a technology demonstration built by a Goddard team under Dr. Matthew McGill, who serves as principle investigator for the mission. According to the mission's web page, "CATS will extend profile measurements of atmospheric aerosols and clouds from the International Space Station (ISS). The CATS payload will improve our understanding of aerosol and cloud properties and interactions, as well as improve climate change models. CATS is specifically intended to demonstrate a low-cost, streamlined approach to developing ISS science payloads."¹

CATS uses state-of-the-art light detection and ranging (lidar) systems electronics and advanced laser technology developed by Fibertek, Inc. of Herndon, VA under a Phase-III small business innovation research program (SBIR) award. According to Fibertek, components of the system included payload power supplies, ISS communications hardware and software interface, lidar data collection system, system safety hardware, payload controller, photon counting electronics, and state-of-the-art three-wavelength lasers: ultraviolet (UV), visible, and infrared (IR). Fibertek also provided the ground control station software and user interface, and tested the system using NASA's Johnson Space Flight Center simulator and the Marshall Center's TreK payload interface system.²

The refrigerator-sized CATS module continues and expands on orbital observation of atmospheric aerosols by other instruments including NASA's Cloud-



► Artist concept of CATS. —IMAGE BY NASA

Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission – but with a major difference. Earlier observations were performed only at visible and IR wavelengths. Adding the UV laser will yield more precise results and help to distinguish different types of particles. According to McGill: "You get better data quality because you make fewer assumptions, and you get, presumably, a more accurate determination of what kind of particles you're seeing in the atmosphere."³

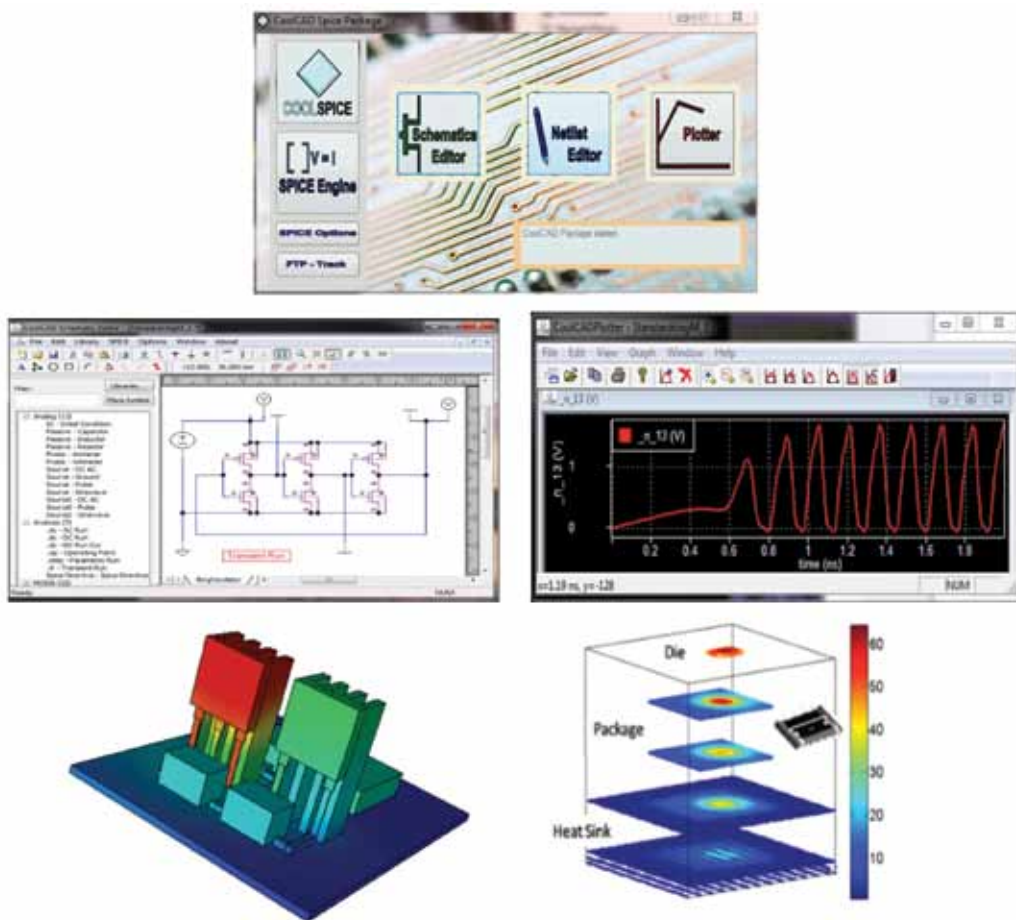
CATS was developed by a small team of just nineteen NASA scientists and engineers, operating on a very short timeline: Just two years from concept to launch. According to McGill, the small team was key to getting the experiment built in time: "Pick the right people, trust them, empower them, then trust them again, and you'll be amazed." The instrument is expected to deliver results for up to three years.⁴

Electronics Modeling and Design for Cryogenic and Radiation Hard Applications and Silicon Carbide-based Ultraviolet Detectors

CoolCAD Electronics, LLC of College Park, MD has developed a suite of computer aided design tools capable of dealing with harsh orbital radiation and temperature environments. The company's CoolSPICE suite is capable of modeling the effects of harsh conditions on state-of-the-art complementary metal-oxide semiconductor (CMOS) devices. Goddard supported the research with an SBIR for development of electronics to support future missions to destinations such as Jupiter's icy moon, Europa. The U.S. Army has since invested an additional \$390,000

and the Office of the Secretary of Defense added \$1,150,000 for the development of CoolSPICE for Silicon Carbide (SiC) power electronics applications. CoolCAD also reports that a demonstration version of the software has been downloaded more than 7,000 times since its release.

Under a separate SBIR, CoolCAD is working on SiC-based ultraviolet detectors for future NASA heliophysics and planetary missions. The company is in discussion with a potential licensee interested in using the technology for consumer radiation detectors, and also believes there may be applications in fields ranging from healthcare and sanitation to national defense.



► **CoolSPICE Circuit Design Tool:** (Top) Graphical User Interface tool launcher; (Middle) Circuit Schematic Editor and Graphical Output Display of simulated circuit operation; (Bottom) Thermal simulation of transistors on printed circuit board and temperature calculation of a chip, package and heat sink.

¹"CATS: Cloud-Aerosol Transport System," NASA web page, <http://www.nasa.gov/cats/#.VN0p9y4WLK3>, (accessed February 12, 2015).

²"Fibertek Delivers Technology for NASA Earth Science Missions," Fibertek, Inc. web site, <http://www.fibertek.com/news/FibertekdeliverstechnologyforNASAearthsciencemission.html>, (accessed February 12, 2015).

³Lisa-Natalie Anjozian, "Testing CATS in Space: Laser Technology to Debut on Space Station," NASA web page, http://www.nasa.gov/mission_pages/station/research/news/cats_in_space/#.VN0sNS4WLK0, (accessed February 12, 2015).

⁴Kasha Patel, "NASA's CATS: A Launch of Exceptional Teamwork," NASA web site, <http://www.nasa.gov/content/goddard/nasa-s-cats-a-launch-of-exceptional-teamwork/#.VN0v8y4WLK0>, (accessed February 12, 2015).



► Innovative Technology Partnerships Office (ITPO) Technology Manager, Enidia Santiago-Arce, speaks to attendees at the Big Data Forum about NASA's Big Data opportunities and capabilities.

—PHOTO BY NASA

Big Data Forum

(OCTOBER 9, 2014, GREENBELT, MD)

On October 9, 2014, the Innovative Technology Partnerships Office (ITPO) hosted a Technology Commercialization Big Data Forum to discuss Big Data commercialization, partnerships, and licensing opportunities. Dr. John Schnase (Code 606) and Dr. Dan Duffy (Code 606) spoke with attendees about Goddard's role in the realm of Big Data. Topics that were discussed included Big Data management and transfer, mining and analysis; How outside companies may collaborate with Goddard; What Big Data tools NASA utilizes; and discussed the NASA Center for Climate Simulation (NCCS) and the Modern Era Retrospective-analysis for Research and Application (MERRA). Attendees also toured the supercomputing facility and participated in individual follow-up briefings

with innovators and a Tech Manager from the ITPO. Attendees from nearly 40 small businesses, other government agencies, TEDCO and GSFC were in attendance.

7th Annual NASA Supply Chain Quality Assurance Conference

(OCTOBER 21 - 23, 2014, GREENBELT, MD)

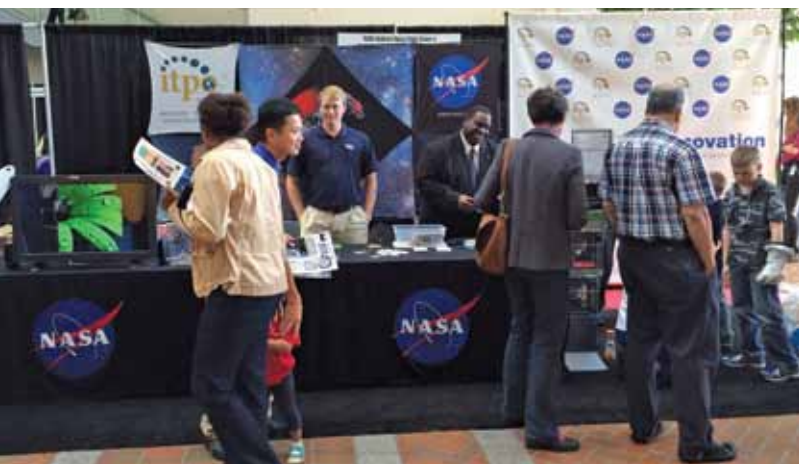
The Innovative Technology Partnerships Office (ITPO) participated in the 7th Annual NASA Supply Chain Quality Assurance Conference, October 21-23, 2014 at Goddard. The ITPO provided information to 200+ attendees on tech transfer, partnership & licensing opportunities, and SBIR/STTR. During the 3-day conference several speakers discussed topics such as

NASA's Science and Exploration Missions and risk management. A tour of GSFC facilities was also offered to interested participants.

United States Patent and Trademark Expo

(OCTOBER 16 - 17, 2014, ALEXANDRIA, VA)

The Innovative Technology Partnership's Office (ITPO) participated in the National Trademark Expo at the United States Patent and Trademark Office (USPTO) in Alexandria, VA, October 16-17, 2014. As one of over 40 exhibitors, the ITPO talked with attendees about current trademarks, including SpaceCube (registered trademark no. 4172242). Many attendees asked about trademarking the NASA logo & learned that NASA's logo does not need to be registered by trademark because it is protected from use under statute (U.S. law 14 CFR 12221). The NASA logo is a *statutory trademark*. Guests also learned about the Goddard OPTIMUS PRIME Challenge, created their own technology innovation & had their picture taken with astronaut gloves in front of the ITPO's *I am innovation* backdrop. An estimated 14,000 people attended over the two days.



► *Innovative Technology Partnerships Office (ITPO) Technology Maganger, Dennis Small, and Technology Commercialization Specialist, Louis Mari, talk with attendees at the 2014 United States Patent and Trademark Expo.*

—PHOTO BY NASA

Association of University Technology Managers

(OCTOBER 22 - 23, 2014, HOUSTON, TX)

The Innovative Technology Partnerships Office participated in the Association of University

Technology Managers (AUTM) Partnering Forum in Houston, TX on October 22-23, 2014. This annual forum offers attendees an opportunity for technology transfer and licensing specialists from universities and research institutions, to connect with their counterparts in business development and intellectual property from the gas and oil industry. Several fruitful discussions were held with these industry reps to explore potential energy research collaborations and licensing opportunities.



► *Innovative Technology Partnerships Office (ITPO) Technology Commercialization Specialist, Andrei Zorilescu, challenges children at the 2014 Noche de Ciencias (Science Night), with a puzzle demonstrating how to build different types of structures from various materials.*

—PHOTO BY NASA

2014 Noche de Ciencias (Science Night)

(OCTOBER 23, 2014, ALEXANDRIA, VA)

The Innovative Technology Partnerships Office (ITPO) participated in Noche de Ciencias (Science Night) at T.C. Williams High School in Alexandria, VA, on October 23, 2015. This annual event is hosted by the Society of Hispanic Professional Engineers (SHPE), and caters to local students interested in a career in science and engineering. Several engineering firms and local universities, were on hand to speak with attendees about opportunities in various technology related fields. The ITPO spoke with visitors about technology transfer, NASA Spinoffs and promoted its popular OPTIMUS PRIME Spinoff Video Contest.

Exelon Innovation Expo

(NOVEMBER 4, 2014, BALTIMORE, MD)

The Innovative Technology Partnerships Office (ITPO) was invited to participate in the Exelon Innovation Expo on November 4, 2014 in Baltimore, MD. Approximately 450 Exelon employees and management executives attended to learn more about emerging technologies. The ITPO featured several technologies of potential licensing interest to attendees, including NASA's Lotus Coating, Graphene, Hierarchical Image Segmentation (HSEG), and Gear Bearing technologies.

Innovative Initiatives with Steven Johnson

(NOVEMBER 13, 2014, GREENBELT, MD)

To facilitate a conversation about managing innovations (both technology and business management practices), Goddard management, scientists, engineers, and innovators were invited to participate in the Innovative Technology Partnerships Offices (ITPO) Innovative Initiatives Workshop Fall 2014 on November 13, 2014. Steven Johnson, author of *How We Got to Now: Six Innovations That Made the Modern World*, and host of the PBS series *How We Got to Now* with Steven Johnson, spoke with over 100 attendees about exploring connections between often unrelated disciplines and how these subjects are sometimes interdependent and essential to the collective interest at Goddard. Mr. Johnson also co-facilitated a Roundtable Meeting with Center management.



► Steven Johnson, author of *How We Got to Now: Six Innovations That Made the Modern World* and host of the PBS series *How We Got to Now* with Steven Johnson, addresses attendees at the ITPO's Innovative Initiatives workshop at NASA Goddard.

—PHOTO BY NASA

Goddard Innovator Training

(NOVEMBER 19, 2014, GREENBELT, MD)

The Innovative Technology Partnerships Office (ITPO) conducted a training on November 19, 2014 at NASA Goddard Space Flight Center (GSFC) on what NASA innovators need to know about how partnerships are formed with industry, and how NASA inventions are advanced. The training was provided by Joseph Holmes, Professor of Innovation at Duke University. Items discussed included partnership strategies, how ITPO supports NASA innovators with commercial partnerships and advancing the TRL of GSFC innovations. Other topics included how NASA innovators benefit from technology transfer and the ITPO and the America Invents Act.



► Innovative Technology Partnerships Office Senior Technology Manager Darryl Mitchell, demonstrates NASA AeroPod technology to attendees at the 2014 Chicago Toy and Game Fair.

—PHOTO BY NASA

Chicago Toy and Game Fair (ChiTAG)

(NOVEMBER 22- 23, 2014, CHICAGO, IL)

The Innovative Technology Partnerships Office (ITPO) attended the Chicago Toy & Game Fair (ChiTAG) on November 22-23, 2014 at the Navy Pier in Chicago, IL. ITPO Chief, Nona Cheeks, was the keynote speaker at the International Toy & Game Innovation Conference on November 21, 2015. ITPO met with several toy developers and company executives regarding partnerships with NASA Goddard Space Flight Center. Highlighted technologies included Gear Bearings and Aeropods. Approximately 10,000 people attended ChiTAG. ITPO provided information about partnering with NASA and the Goddard OPTIMUS PRIME Spinoff Challenge. In addition, educational toy kits developed as a result of a partnership between Goddard and littleBits Electronics were highlighted.



► Innovative Technology Partnerships Office SBIR/STTR Deputy Program Manager Ramsey Smith (right) talks with an attendee at the 2014 Annual IRAD Poster Session.

—PHOTO BY NASA

NASA Goddard Internal Research and Design (IRAD) Poster Session

(DECEMBER 12, 2014, GREENBELT, MD)

Goddard Space Flight Center's Innovative Technology Partnerships Office (ITPO) exhibited at the Annual IRAD Poster Session to take part in inreach activities involving technologies and concepts that Goddard's IRAD program funded this past fiscal year. At this annual event showcasing research and development achievements, the ITPO looked to connect, share ideas

and create new partnerships that could lead to new technologies. The ITPO aimed to reach out to attendees regarding how the ITPO manages partnerships that start with the submission of New Technology Reports (NTRs). ITPO staff met with scientists and engineers exhibiting at the poster session to learn of new technologies developed and ensure the submission of new technology reports and identify areas where the ITPO can potentially help facilitate new partnerships. The ITPO distributed Tech Transfer and Tech Briefs magazines, and talked with attendees about partnership opportunities.

Technology Disclosures

Disclosures

GLOBE PROGRAM'S DATA ENTRY APP FOR ANDROID

DATABASE FOR PLANETARY PROTECTION BIOBURDEN ASSAYS

UNIVERSAL AND AUTOMATED MONTE CARLO METHOD CODE FOR UNCERTAINTY PROPAGATION IN LARGE VOLUME METROLOGY DATABASES

SEED-DERIVED SECOND HARMONIC SOURCE FOR IN SITU MODIFICATION OF REACTION/MOMENTUM WHEELS FOR ULTRA-PRECISION POINTING

OCTOCOPTER WITH DYNAMIC INVERSION CONTROL SOFTWARE TO EMULATE SPACECRAFT

WINGSONDE A SMALL, TUBE-DEPLOYED, UNMANNED AIRCRAFT DEVELOPED FOR ATMOSPHERIC SENSING

A MULTI-DEPTH UNDERWATER SPECTRORADIOMETER FOR VALIDATION OF REMOTELY SENSED OCEAN COLOR AND ESTIMATION OF SEAWATER BIOGEOCHEMICAL PROPERTIES

MMS MAGNETOMETER DATA PROCESSING SOFTWARE

A COMPACT, SOLID-STATE UV (266 NM) LASER SYSTEM FOR LASER ABLATION/ DESORPTION

LVFS: A SCALABLE VIRTUAL FILE SYSTEM

WALP: WINGSONDE AERIAL LAUNCH RACK, A MODULAR LAUNCH RACK FOR AERIAL VEHICLE DEPLOYMENT

SPEED BRAKE FOR ACCELERATED DEORBIT OF SPACECRAFT WITH UNCONTROLLED ENTRY

HARDWARE ACCELERATED HISTOGRAMMING FUNCTION

A ROBUST AND AUTOMATED HYPERSPECTRAL DAMAGE ASSESSMENT SYSTEM UNDER VARYING ILLUMINATION CONDITIONS AND VIEWING GEOMETRY

PARAMAT PARALLEL ENHANCEMENTS TO GMAT

GLOBE PROGRAM'S DATA ENTRY APP FOR IOS

GLOBE PROGRAM'S CITIZEN SCIENCE CLOUD APP FOR IOS

SURFACE FIELD ENHANCED DETECTION OF DEEP UV PHOTONS IN SILICON CARBIDE AVALANCHE PHOTODETECTORS

A METHOD FOR THE ABSOLUTE CALIBRATION OF THE LOCATION AND ORIENTATION OF LARGE-FORMAT DETECTORS USING LASER RADAR

A NEW CLASS OF FLARE PREDICTION ALGORITHMS: A SYNTHESIS OF DATA, PATTERN RECOGNITION ALGORITHMS, AND FIRST PRINCIPLES MAGNETOHYDRODYNAMICS

GIMBAL PLATFORM FOR EARTH SCIENCE PAYLOADS ON INTERNATIONAL SPACE STATION (ISS)

LARGE AREA NANOWIRE GROWTH APPARATUS AND PROCESS

LOW-COST WINDPROBE FOR USE IN A UAV ATMOSPHERIC SENSOR PLATFORM

FREQUENCY DIVERSITY PULSE PAIR ALGORITHM FOR MITIGATION OF RADAR RANGE-DOPPLER AMBIGUITY

DUALBAND MW/ LW STRAINED LAYER SUPERLATTICE FOCAL PLANE ARRAYS FOR SATELLITE-BASED WILDFIRE DETECTION

PRINTED PHASE CORRECTOR PLATE

SPINOFF 2015 IPAD APP

MODIFICATION OF
REACTION/MOMENTUM
WHEELS FOR ULTRA-
PRECISION POINTING

MINATURE KA-BAND
AUTOMATED SWATH
MAPPER

MICROFABRICATED
ATOMIC MAGNETOMETER
WITH HYBRID VECTOR-
SCALAR OPERATION

METHOD OF MAKING
NANOWIRE SENSORS

Patent Applications Filed

DEVELOPMENT OF A 1,920
X 2,048 (2K X 2K) GAAS
QWIP ARRAY

U.S. Patents Issued

MULTICOLOR DETECTORS
FOR ULTRASENSITIVE
LONG-WAVE IMAGING
CAMERAS
U.S.. PATENT 8,912,494

INTEGRATED GENOMIC
AND PROTEOMIC
INFORMATION SECURITY
PROTOCOL
U.S. PATENT 8,898,479

AN ALL-METAL,
SOLDERLESS CIRCULARLY
POLARIZED MICROWAVE
ANTENNA ELEMENT WITH
VERY LOW OFF-AXIS
CROSS-POLARIZATION
U.S. PATENT 8,912,974

IMPLEMENTATION
PLATFORM FOR NEW
METHODOLOGY OF
REDUCING SENSOR AND
READOUT ELECTRONICS
CIRCUITRY NOISE IN
DIGITAL DOMAIN USING
REFERENCE SPACE PIXELS
U.S. PATENT 8,913,844

COMPANY	AGREEMENT TYPE	PARTNERSHIP ABSTRACT
Space Vector Corporation	Patent License	A non-exclusive Patent License was signed with Space Vector Corporation, Chatsworth, CA, for use of NASA GSFC's "Radiation Hardened Fast Acquisition Weak Signal Tracking System and method, and Global Positioning System (GPS) Enhanced Onboard Navigation System (GEONS)" technologies.
Millennium Space Systems	Patent License	An exclusive Patent License was signed with Millennium Space Systems, El Segundo, CA, for use of NASA GSFC's "Demisable Integrated Reaction Wheel Assembly (DIRWA)" technology.
Sigma Space Corporation	Patent License	An exclusive Patent License was signed with Sigma Space Corporation, Lanham, MD, for the use of NASA GSFC's "3-Dimension Imaging Lidar" technology.



► The SpaceX Falcon 9 rocket carrying the NOAA/NASA joint mission Deep Space Climate Observatory spacecraft, or DSCOVR, lifts off from Space Launch Complex 40 at Cape Canaveral Air Force Station in Florida.

—PHOTO BY NASA

NASA Goddard Tech Transfer News [<http://itpo.gsfc.nasa.gov>]

NASA Goddard *Tech Transfer News* is the quarterly magazine of the Innovative Technology Partnerships Office (Code 504) at NASA's Goddard Space Flight Center. Also available online at: <http://itpo.gsfc.nasa.gov>. Send suggestions to Robert.S.Leonardi@nasa.gov.